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BIONOMICS OF *MICROMUS POSTICUS* (WALKER) (NEUROPTERA: HEMEROBIIDAE) WITH DESCRIPTIONS OF THE IMMATURE STAGES

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Abstract.—The egg and larva of *Micromus posticus* (Walker) are redescribed and illustrated. While setal patterns appear similar for all instars, head capsule dimensions can be used to distinguish between instars. A key to the instars is provided. The life history of *M. posticus* was studied using *Aphis gossypii* Glover as prey. Laboratory-reared females survived an average of 61 days and males an average of 74 days. Adult female survivorship was 100% up to 25 days. Mean total egg production was 933.2 eggs/female, with a maximum of 1484. Net reproductive rate was 461.3 females/female/generation, mean generation time was 56.3 days, intrinsic rate of increase was 0.153 females/female/day, doubling time was 4.5 days, and finite rate of increase was 1.17/individual/day. Laboratory and field observations in east-central Alabama indicated that females oviposited most often on fibrous material such as cotton fibers and spider mite webbing. Pupation in the field on cotton occurred within bracts on bolls and in folds of leaves. *Charitopes mellicornis* (Ashmead) and *Anacharis melanoneura* Ashmead together parasitized 6% of the *M. posticus* larvae in an unsprayed cotton field.

The Hemerobiidae continue to be overlooked despite the widely held belief that they are important predators. Withycombe (1924) ranked them as one of the three most economically important Neuroptera families in Britain. Balduf (1939) considered the hemerobiids the most important Neuroptera next to the Chrysopidae in controlling soft-bodied agricultural pests. Although all hemerobiids are predatory, many are limited in habitat range or exhibit a prey specificity that limits their effectiveness (New, 1975). However, some species do frequent low vegetation, and could be considered for use in many agroecosystems.

Among the species that New (1975) considered to be of agronomic importance were species of the genus *Micromus*. In the Nearctic region, *Micromus posticus* (Walker) has been collected in the eastern United States from Massachusetts west to Minnesota and south to Florida and Texas (Carpenter, 1940) and as far north as Manitoba, Canada (Batulla and Robinson, 1983). The most common species of the genus (Carpenter, 1940), it is associated with a variety of different habitats including mixed forest (Batulla and Robinson, 1983), citrus groves (Muma et al., 1961), pecan orchards (Edelson, 1982), vineyards (Jubb and Masteller, 1977), cotton fields (Whitcomb and Bell, 1964), potato fields (Mack and Smilowitz, 1980) and alfalfa (Smith, 1923). The pest prey of *M. posticus* include the cotton aphid, *Aphis gossypii* Glover, *Aphis spiraecola* Patch, the green peach aphid, *Myzus persicae* (Sulzer), the black citrus aphid, *Toxoptera aurantii* (Fonscolombe), and *Macro-*

siphum sp. (Selhime and Kanavel, 1968), the cabbage aphid, *Brevicoryne brassicae* (L.), and eggs of the imported cabbageworm, *Pieris rapae* (L.) (Cutright, 1923), yellow pecan aphids, *Monellia caryella* (Fitch) and *Monelliopsis nigropunctata* (Granovsky) (Edelson, 1982) and *Uroleucon ambrosiae* (Thomas) (Batulla and Robinson, 1983).

Smith (1922, 1923) and Cutright (1923) provided the first life history accounts of *M. posticus*. Smith (1922) observed hatching and (1923) briefly described the larval instars. Cutright (1923) determined consumption rates of the larvae and included notes on preoviposition time, fecundity, and adult longevity. Selhime and Kanavel (1968) reared *M. posticus* on a variety of aphids at 26.67°C and recorded developmental time. They determined a fecundity of 509 eggs for a single field-collected female.

Identification of the Hemerobiidae continues to be based primarily on adult morphology (e.g. MacLeod and Stange, 1981), while other stages are frequently overlooked. The potential of many hemerobiids as biological control agents is also overlooked. The purpose of this study was to provide morphological descriptions of the egg and larval stages of *M. posticus* and to better qualify and quantify various aspects of its life history.

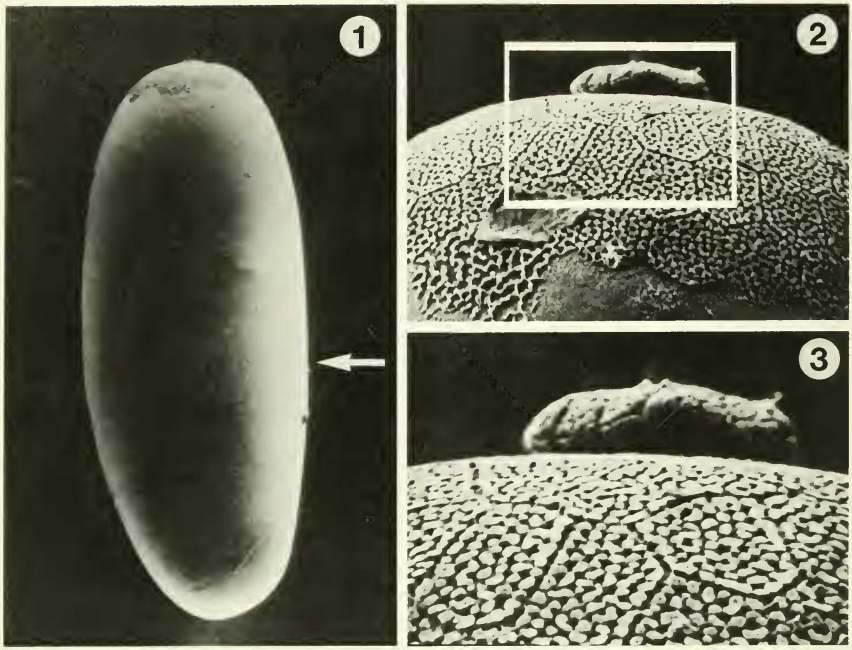
Materials and Methods

Larval and adult *M. posticus* were obtained by rearing eggs and larvae collected from a cotton field near Tallassee, Alabama. Larvae were caged in 50 × 9 mm plastic petri dishes and provided daily with cotton aphids obtained from the field or greenhouse. Voucher material of adults and larvae of *M. posticus* is deposited in the Auburn University Entomological Museum.

Egg morphology.—Eggs were measured with an ocular micrometer using a Wild stereoscope to determine length and width. For examination with the scanning electron microscope, other eggs were removed from 10% formalin preservative, rinsed in distilled water, air dried, mounted on aluminum stubs with double-coated cellophane tape, and coated with gold-palladium alloy in a sputter coater. Egg ultrastructure and ultrastructure measurements of these eggs were determined using an ISI-SS40 scanning electron microscope (SEM) with an accelerating voltage of 5 kV. Photographs were taken with Polaroid 55 film. Measurements were recorded in millimeters (mm) with means followed by ranges in parentheses.

Larval morphology.—Larvae were examined under a Zeiss compound microscope, and measurements were made with an ocular micrometer. Larvae were obtained from the laboratory colony and were preserved and mounted on slides as described by Wilkey (1962). Setal numbers are given for each half of the body. Occasionally, setal pattern is expressed as a formula. For example, the setal pattern 2-1-2 indicates one long and one short seta together, a single long seta, and one long and one short seta together from the midline to the lateral margin. Length of the setae (long or short) is relative to other setae of the same segment being described. Short setae are approximately one-half or less the length of long setae. Measurements were recorded in millimeters (mm) with means followed by ranges in parentheses.

Life table.—Larvae reared from eggs were checked daily for molt to the next instar, cocoon formation, and pupation. Upon eclosion, adult females were transferred individually to 60 × 20 mm petri dishes. A single male accompanied each female. Each mating pair was supplied daily with fresh cotton aphids and a ball of cotton saturated with 10% honey water. A portion of loose cotton fibers was supplied as an oviposition site. Females were checked daily for oviposition and survivorship. Eggs were removed and counted and fresh cotton fibers were placed in the cage. Occasional samples of eggs were saved for rearing to determine time to egg hatch. Dead males were replaced



Figs. 1–3. SEM photographs of *Micromus posticus* eggs. 1, Habitus (arrow indicates side of attachment to substrate) (97×). 2, Anterior pole (469×). 3, Micropyle (939×).

with live ones when necessary. All cages were housed in a rearing room at 28°C and 70–80% RH with a 14L:10D photoperiod.

A survivorship and fertility (= number of offspring produced) table was constructed for adult females by determining for each day, or age interval (x), the proportion of surviving individuals (l_x) and the mean number of female progeny per surviving female (m_x). The sum of the mean developmental times of eggs, larvae, and pupae was used to estimate the age at which adult eclosion occurred. Egg survival was recorded as 100% since rearing of eggs for developmental time, colony maintenance, and viability checks indicated complete egg hatch. Due to exclusion of cannibalism, disease and natural enemies, survivorship was also 100% for larvae and pupae. Sex ratio was assumed to be 50:50. This assumption is supported by our determination of the sex ratio of field-collected individuals and the findings of Deyrup and Deyrup (1978), who reported rearing nearly equal numbers of both sexes from field-collected pupae of five species of hemerobiids. Life table statistics were calculated as follows: R_o, the net reproductive rate, is the sum of the products $l_x \cdot m_x$ calculated for each age interval; G, the generation time, is the sum of the products $l_x \cdot m_x \cdot x$ divided by R_o; r, the innate capacity for increase, was calculated by substituting values of r into the equation: $\Sigma (l_x \cdot m_x \cdot e^{-rx}) = 1$ until equilibrium was reached; and λ, the finite rate of increase, was calculated as e^r.

Field observations.—From July–September 1984, field observations of the life history of *M. posticus* were recorded from an

unsprayed cotton field 3.2 km S of Tallassee, Elmore Co., Albama, which was heavily infested with cotton aphids. The field was sampled at the end of the growing season (1 September) to determine density of cocoons per plant. Density was estimated by visually sampling 50 plants chosen at random, 10 in each of the four corners and in the center of the plot.

Results

Descriptions of immature stages

Egg.—(n = 15): Length .91 mm (.88–.96), width .42 mm (.38–.46). Ellipsoidal, slightly flattened on surface attached to substrate (Fig. 1); pale yellow to cream colored after deposition, darkening to pinkish brown prior to hatching. Eyespots and abdominal striations from developing embryo visible through chorion before eclosion. Chorion primarily smooth but exhibits high concentration of irregular projections near micropylar pole (Fig. 2); projections occasionally separated by fissures to form irregularly shaped polygons (Fig. 3) but are usually interconnected by narrow bridges basally. Prominent, buttonlike micropyle, height .005 mm, width .045 mm, present on center of anterior pole. Anterior pole slightly darker than remainder of chorial surface, color of micropyle remaining chalk-white throughout embryonic development.

Third instar.—(Fig. 4a–d) (n = 10): Length 7.96 mm (6.28–9.50), width at metathorax 1.35 mm (.98–1.75). *Head Capsule*: Length .59 mm (.55–.61), width .59 mm (.57–.62). Head prognathous, Y-shaped ecdysial line terminating at base of mandibles and running medially to posterior margin of head; frons deltoid with two long setae on frontoanterior margin and 1 on lateral margin. Gena with 5 long setae in center, 3 short setae on posterior margin of sclerite, 2 long setae on lateral margin near 3 corneal swellings, and 3 long setae and 1 short seta ventrally. Antenna three segmented, extending well beyond tips of jaws; scape .10 mm (.09–.12) long, .09 mm (.08–.11) wide; pedicel .99 mm (.93–1.02) long, .043 mm (.037–.049) wide; flagellum .32 mm (.30–.34) long gradually tapering to a long apical bristle. Pedicel and flagellum with irregular annular sclerotizations. *Cervix*: Venter with 3 small anterolateral setae, 3 long median setae in vertical row, 3 long median setae in oblique row, 2–4 long lateral setae; dorsum with posterior row of 3–4 long setae, 3–4 submedian setae in vertical row, 2–3 long anteromedial setae. *Prothorax*: Anterior subsegment: Venter with 3 short setae near anteromedial margin, 2 short median setae, 3 long setae in anterior transverse row, 2 long median setae and 1 short posterior seta; dorsum with 3 short setae on anterior mediolateral margin, 3 long setae in anterior transverse row, 1 long seta posterior to preceding row of setae, 2–3 long median setae, median sclerite with 2 long setae and 1 short seta, and a transverse row of 3 long setae near posterior margin, 2 long setae laterally. Posterior subsegment: Venter covered with microspines only; dorsum with 1 short seta on anterior submedian margin, 1 short submedian seta, median transverse row of 4–6 long setae, a spiracle and long seta laterally. *Mesothorax*: Anterior subsegment: Venter with 2 short setae on anterior submedian margin, 1 short seta near anteromedial margin, circulet of 4–5 long anterolateral setae, 2 long median setae; dorsum with 2 anterior submedial short setae and transverse row of 4–5 long setae, median transverse row of 3 long setae, posterior row with 4 long and 1–2 short setae, 2–3 long setae near lateral margins. Posterior subsegment: Venter with microspines only; dorsum with 2 short setae anterosubmedially and a transverse row of 6–7 long median setae. *Metathorax*: Venter with 2 short setae on anterior sublateral margin, 1 short seta on anterior submedial margin, 5–6 long setae in anterolateral cluster, 2 long submedian setae; dorsum with 1 anterior submedian short seta and transverse row of 4 long setae, median transverse row with 3 long setae, 2–3 lateral setae and

a short seta on small sclerotized area, posterior transverse row of 4 long setae, 3–4 long lateral setae. *Abdomen*: Segment I: Venter with 2 long median setae; dorsum with 1 short seta on anterior sublateral margin, 1 short seta near anterior submedian margin, anterior transverse row of 3 long setae, posteriorly with a transverse row of setae with either a single long seta or a long and short seta on small sclerotized areas arranged 2-1-2, from midline to lateral margin, spiracle and 2 long setae laterally. Segment II: Venter with 2 short setae and 2 long setae near anterior margin, posterior row of long and short setae arranged 1-1-2 from midline to lateral margin; dorsum with anterior subdivision with 1–2 short anterosubmarginal setae, posterior subdivision with anterior transverse row of 3–4 long setae, posterior transverse row of long and short setae arranged 2-1-2 from midline to lateral margin, spiracle and 2 long setae laterally. Segment III: Venter with 2 short setae and 2 long setae near anterior margin, posterior transverse row 1-1-2 midline to lateral margin; dorsum with anterior subdivision with 1–2 short anterosubmarginal setae, posterior subdivision with anterior transverse row of 3 long setae and 1 short seta between inner 2 setae, posterior transverse row of long and short setae arranged 2-1-2 from midline to lateral margin, spiracle and 2 long setae laterally. Segment IV: Venter with 2 setae anteriorly and 3 short setae approximately midway between these setae, posterior row of long and short setae arranged 1-1-2 from midline to lateral margin; dorsum same as abdominal segment III. Segment V: Venter with 2 long setae anteriorly and 2 short setae slightly above innermost seta, posterior transverse row of long and short setae arranged 1-1-2 from midline to lateral margin; dorsum same as abdominal segment III. Segment VI: Venter with 1–2 short setae above innermost anterior long setae, posterior transverse row of long and short setae arranged 1-1-2 from midline to lateral margin; dorsum same as segment III. Segment VII: Venter same as segment VI; dorsum same as segment III. Segment VIII: Venter with 2 long setae anteriorly and 2 small pores and a short seta above the innermost long seta, posteriorly with a transverse row of long and short setae arranged 1–2 from midline toward lateral margin; dorsum same as segment III except lateral setae lacking. Segment IX: Venter with 1 long seta medially, 2 pores and a short seta adjacent to long seta, posterior transverse row of long and short setae arranged 1–2 from midline to lateral margin; dorsum with anterior subsegment with microspines only, posterior subsegment with anterior transverse row of 2 long setae and 1 short seta anteromedially to these setae, posterior row of long and short setae arranged 2-1-2 from midline to lateral margin, 1–2 small pores above innermost setae, spiracle absent, 1 long anterolateral seta. Segment X: sclerotized with dorsal deltoid plate, lateral plates, and ventral deltoid plate. Venter with 2 long setae and 2 pores on inner anterior margin of lateral plates, 1 long lateral seta on lateral plate, 3 short setae on posterior margin of ventral deltoid plate; dorsum with 3 long setae on outer margin, 1 median pore and 3–4 shorter setae on basal margin of deltoid sclerite, 2 long setae on inner margin of lateral plate.

Second instar.—(n = 10): Differing from third instar as follows: Length 5.48 mm (4.73–6.03); width at metathorax .86 mm (.59–1.0). *Head Capsule*: Length .42 mm (.40–.46), width .42 mm (.40–.43). Antennal scape .073 mm (.062–.093) long, .060 mm (.056–.093) wide; pedicel .65 mm (.58–.71) long, .038 mm (.037–.043) wide; flagellum .29 mm (.27–.32) long. *Cervix*: Venter with 4–6 setae arranged randomly from midline to lateral margin; dorsum with 4–5 setae in posterior row, 6–8 setae arranged randomly from midline to lateral margin. *Prothorax*: Anterior subsegment: Venter with 5 short anterolateral setae; dorsum with 0–3 short setae near anteromedial margin, 10–14 long and short setae arranged ran-

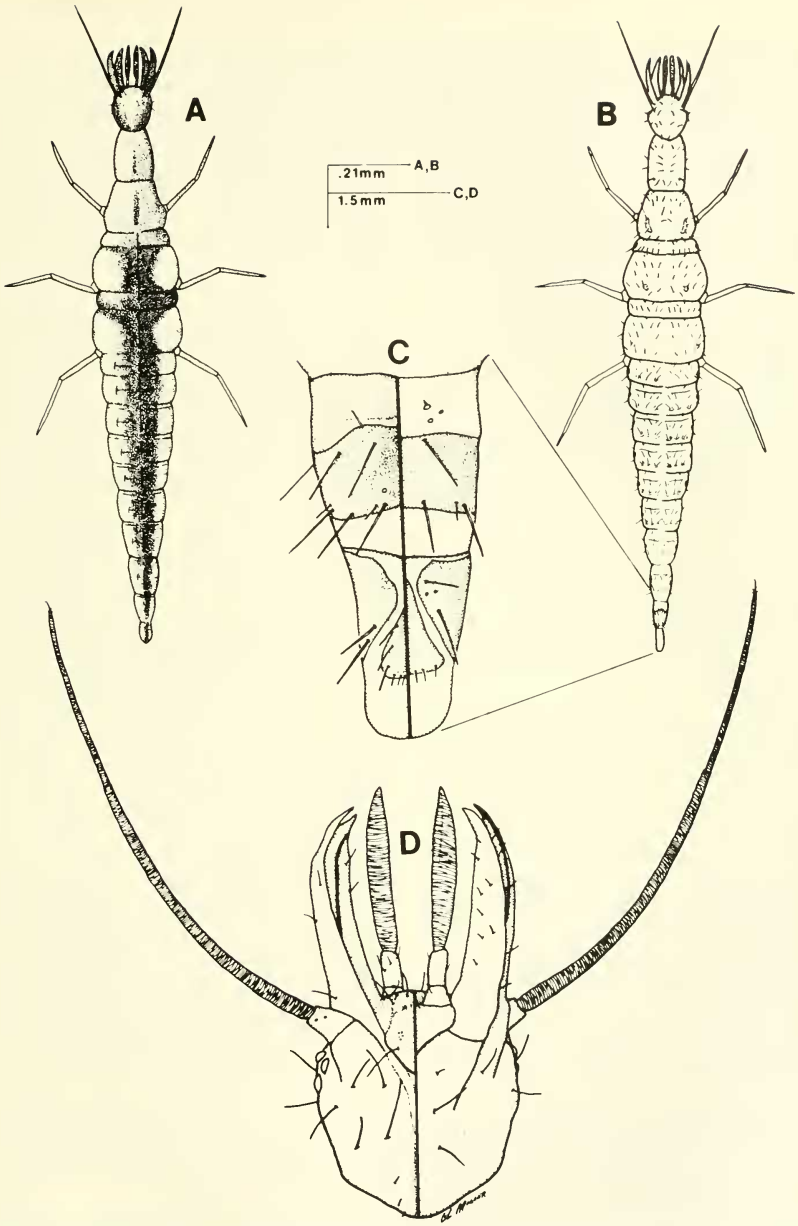


Fig. 4. *Micromus posticus* third instar. A, Dorsal habitus. B, Dorsal setal pattern. C, Ninth and 10th abdominal segments (dorsum and venter). D, Head capsule (dorsum and venter).

domly from midline to lateral margin (setal pattern may resemble that of third instar). Posterior subsegment: Dorsum with 2 short submedian setae, median transverse row of 4 long setae. *Mesothorax*: Anterior subsegment: Venter with circulet of 4–6 long setae, 1 short seta posterolateral to posteromedial long seta; dorsum with 3 long setae in anterior transverse row, median transverse row of 2 long setae and 1 short seta near lateral margin. Posterior subsegment: Dorsum with 1 short seta near anterior margin, 2 short setae posterior to anterior marginal seta and median transverse row of 6 long setae. *Metathorax*: Dorsum with ill-defined median transverse row of setae but 2 long mediolateral setae and 1 long medial seta, posterior transverse row with 1 short and 3 long setae. *Abdomen*: Segment II: Venter with 1 short seta near anterior margin; dorsum occasionally with 1 additional long seta in posterior transverse row. Segment IV: Venter with 1 short seta near anterior margin; dorsal anterior subdivision more noticeable than in previous segments and with only 1 small median seta. Segment V: Venter with 2 long setae anteriorly and 1 short seta slightly above innermost long seta; dorsum with anterior subsegment with 1 short median seta. Segment VI: Venter with anterior oblique row of 2 setae and 1 short seta slightly above innermost long seta. Segment VII: Venter with anterior oblique row of 2 setae, sometimes with 2 short setae between innermost long seta. Segment VIII: Venter with posterior transverse row arranged 1-2-2 from midline to lateral margin; dorsal posterior subsegment without lateral setae, integument of posterior transverse row of setae more heavily sclerotized. Segment IX: Venter with 2 long setae in anterior transverse row and 1 short seta slightly above innermost, posterior transverse row of long and short setae arranged 2-1-2 from midline to lateral margin; posterior submargin dorsally with 2 long setae in anterior transverse row.

First instar.—(n = 10): Differing from third instar as follows: Length 3.04 mm (2.43–3.55), width at metathorax .51 mm (.34–.64). *Head Capsule*: Length .30 mm (.26–.32), width .33 mm (.30–.37), 4 long setae and 1 short seta on gena and 4 long setae and 1 short seta on venter. Antennal scape .055 mm (.037–.062) long, .055 mm (.043–.062) wide; pedicel .46 mm (.43–.48) long, .036 mm (.031–.043); flagellum .29 mm (.23–.34) long. Palpi more robust. *Cervix*: Venter with only 3 small anterolateral setae; dorsum with minute spinules only. *Prothorax*: Anterior subsegment: Venter without anterior transverse row of long setae, occasionally 2 short median setae; dorsum with 2 long and 1 short anterior seta, 1 long mediolateral seta, and a posterior transverse row of 3–4 long setae. Posterior subsegment: Dorsum without transverse row of long setae and long lateral setae. *Mesothorax*: Anterior subsegment: Venter with 2–3 short setae on anterior submedian margin, 1 short median seta, and a group of 5–6 short setae laterally; dorsum variable but usually with 2 short setae near anterior submargin, anterior transverse row of 3–5 long setae, posterior transverse row of 3–4 long setae and 1–2 long lateral setae. Posterior subsegment: Dorsum with 2 short anterolateral setae only. *Metathorax*: Venter variable but usually with 2 short setae on anterior sublateral margin, 1 short seta on anterior submedial margin, anterior transverse row of 2–3 long setae, 1–2 long posterior setae; dorsum without noticeable median transverse row of setae, posterior transverse row of 3 long setae, lateral setae variable. *Abdomen*: Segment I: Dorsum with 2 long setae in anterior transverse row. *Legs*: Tarsi with trumpet-shaped empodia.

For quick identification, first instars are distinguished by the presence of tarsal empodia. Second instars can be separated from third instars by head capsule dimensions.

Biology

Table 1 summarizes the developmental times for the immature stages of *M. posticus*

Table 1. Developmental time (days) of *Micromus posticus* immature stages at 28°C.

	Egg	First Instar	Second Instar	Active Third Instar	Quiescent Third Instar	Pupa
Mean	3.5	2.5	1.4	1.9	2.5	3.9
Mode	4	3	1	2	2	4
n	115	29	18	24	61	65

at 28°C. Eggs hatched between 3 and 4 days after deposition. Newly emerged larvae readily fed on small aphids, drank from water droplets, or cannibalized other larvae and eggs if no other food source was available. Duration of the first instar was 1–5 days. The shortest instar developmental time was that of the second, which lasted 1–2 days. Third instars were active and fed for 1–4 days, then formed a loosely spun two-layered cocoon (Fig. 11). A non-feeding, quiescent period of 2–5 days was spent within the cocoon prior to pupation. The mean total time larvae were active and feeding on cotton aphids was 5.8 days. Duration of the pupal stage was 2–5 days.

Mean longevity of adult males exceeded that of adult females by nearly two weeks (Table 2). Student's *t*-test revealed these means are significantly different ($t = 2.149$, $df = 38$, $P < 0.05$). One female lived 86 days and two lived 85 days. Seven males lived longer than 85 days, the maximum being 100 days.

The age-specific survivorship curve for adult female *M. posticus* in the laboratory is shown in Fig. 5A. Initial survivorship was very high; the percentage of females surviving to age 25 days was 100%, and 96% for

Table 2. Longevity (days) of adult male and female *Micromus posticus* at 28°C.

Sex	$\bar{x}$ (±SD)	Range	N
Male	73.8 ± 16.2[1]	45–100	17
Female	61.0 ± 20.2	25–86	23

[1] Means are significantly different (*t*-test; $P < 0.05$).

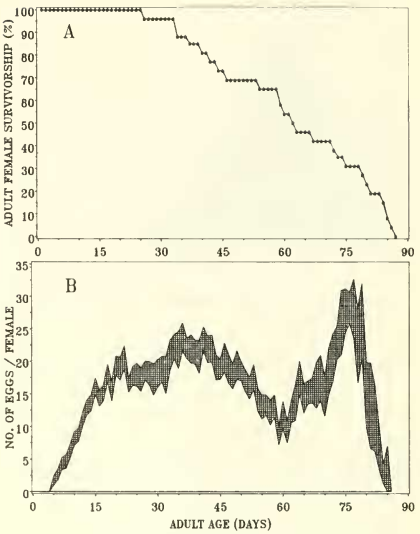


Fig. 5. Age-specific survivorship (A) and age-specific egg production (B) of adult female *Micromus posticus* at 28°C. Shaded area in (B) encompasses 1 standard error above and below the daily mean.

eight days thereafter. Following this, there was a steady decline in survival except for a few short plateaus which are probably sample artifacts.

Mean preoviposition period was 7 days (range 4–12) and mean oviposition period was 54.3 days (range 21–79). The mean number of eggs produced by the 26 females studied was 933.2 (range 298–1484). The most frequent daily clutch sizes were 14 and 17 eggs per day (Fig. 6). Sixty-seven percent of the clutch sizes were between 10 and 29 eggs. Ten percent were greater than 30 eggs. The greatest number of eggs laid by a female in our study in one 24 h period was 58. This female laid 44 eggs the day before laying 58 and oviposited another 43 the day after for a total of 145 eggs in 72 h.

The pattern of age-specific egg production per female had two peaks (Fig. 5B). Mean daily egg production rose to an initial peak of 23.4 eggs/female on day 41. A second

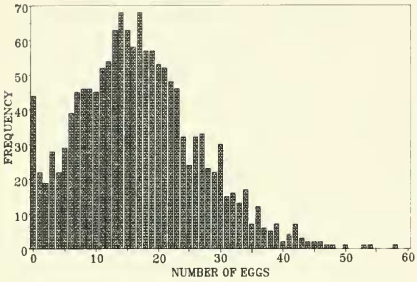


Fig. 6. Observed frequencies of daily egg clutch sizes.

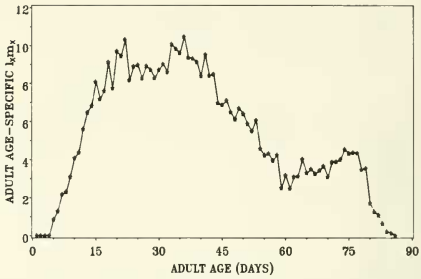


Fig. 7. Age-specific survivorship·fertility ($l_x \cdot m_x$) of *Micromus posticus*.

higher peak of 28.2 eggs/female occurred on day 76. Due to reduction in adult survivorship through time (Fig. 5A), the second peak was based on an average of only eight females, but all of these females displayed this second peak in each of their individual oviposition patterns. This suggests that, although 31% of the initial cohort survived for 76 days, females that survived this long were still capable of producing large numbers of eggs similar to or greater than younger females.

Plotting the product of age-specific survivorship and fertility ($l_x \cdot m_x$) against age (x) shows that the cohort as a group is most productive from 18–43 days (Fig. 7). The egg production peak displayed by individual females around age 76 days was dampened by the reduced survival of females, but was still evident due to the large number of eggs laid by the remaining females at this age.

Using the data obtained in this study, a survivorship and fertility table were constructed and statistics describing the population growth potential of *M. posticus* were calculated. The net reproductive rate (R_o), or the number of times a population multiplies per generation, was 461.3 females/female/generation. Mean generation time (G) was calculated as 56.3 days. The intrinsic rate of increase (r) was 0.153 females/female/day with a resulting doubling time (DT = (ln 2)/r) of 4.5 days. The intrinsic rate of increase was converted into a finite rate of increase of 1.17 per individual per day.

Field Observations

We have observed *M. posticus* eggs and larvae in flowering crimson clover, *Trifolium incarnatum* L., fields containing large infestations of the pea aphid, *Acyrthosiphon pisum* (Harris), in April. Adults were collected at incandescent lights in residential areas and near wooded areas in April and May.

Although an occasional egg was found during June and July, eggs were not seen on most cotton plants until the first week of August. By 26 July, nearly all plants were heavily infested with large colonies of the cotton aphid. By mid-August, nearly every plant harbored numerous eggs and larvae of *M. posticus*. About one week later, the aphid population began to subside; possibly due to parasitism, fungal disease, and predation by *M. posticus* and coccinellids. Nearly all aphid colonies on the cotton terminals were eliminated, while a few remained on the lower leaves. At this time, eggs and larvae of *M. posticus* became less abundant as pupae became more abundant. By late August and early September, adults were more common in the field than at any other time and relatively few eggs, but no larvae, were observed. No adults or larvae were ob-

served in the unsprayed cotton field after mid-September.

Females usually laid several eggs separately on the undersides of leaves, in leaf folds, or on leaf petioles. Females apparently preferred to oviposit on fibrous substrates. On leaf petioles, eggs were often attached to plant trichomes (Fig. 8). Eggs on leaves were most often deposited on the webbing of the two-spotted spider mite, *Tetranychus urticae* Koch (Fig. 9), although neither *M. posticus* larvae nor adults fed on mites in the laboratory. Eggs were also once observed on an abandoned spider web in the field.

Pupation sites were mostly within the bracts of large green bolls on the lower portions of plants (Fig. 10). Cocoons were found less frequently within tight, twisted folds of senescing green leaves and dead, dried leaves hanging on the plant or lying on the ground. The mean number of cocoons per plant was 5.0 ± 0.7 (SE). Half the plants sampled had 4 or more cocoons, with 18 the maximum. There were often 2 or more cocoons on a single boll (Fig. 10). One boll had 12 cocoons within its bracts.

Upon adult emergence, the sex of 52 individuals collected either as eggs, larvae, or pupae was determined. The sex ratio (30:22 females : males) was not significantly different ($\chi^2 = 1.33$; df = 1; $P < 0.05$) from a 1:1 ratio.

On 1 September, two species of Hymenoptera were found parasitizing *M. posticus* pupae: *Charitopes mellicornis* (Ashmead), an ectoparasitic ichneumonid; and *Anacharis melanoneura* Ashmead, an endoparasitic figitid. Of 252 cocoons examined, 15 (6%) were parasitized by these parasitoids. These 15 parasitized hosts were distributed among 11 plants, none of which contained fewer than five *M. posticus* cocoons.

Discussion

Our egg measurements were greater than Smith's (1923) findings of 0.66 mm long and 0.40 mm wide at the largest diameter. Smith (1922, 1923) described the egg chorion as unsculptured and without reticulations. Our investigation with the SEM revealed a sculptured chorion of interconnected projections around the anterior pole. These projections are similiar to those found on the eggs of *Chrysoperla carnea* (Stephens) (Mazzini, 1976) and *Hemerobius stigma* Stephens (Miller and Lambdin, 1982). The micropyle of *M. posticus* is not as pronounced as that of *H. stigma* (Miller and Lambdin, 1982), but the tubercles and fissures described on the micropylar surface of *H. stigma* appear similar in *M. posticus*. Smith (1922) described the hatching process and illustrated the egg burster of *M. posticus*.

Although body and head capsule sizes were not considered reliable characters for determining instars of *H. stigma* (Miller and Lambdin, 1984), we found that these characters are more uniform in *M. posticus*. Except for some individual variability, chaetotaxy is relatively consistent throughout the three instars and is therefore not a good basis for separating the instars of *M. posticus*. This agrees with Withycombe's (1923) belief that chaetotaxy probably does not provide useful taxonomic characters.

Our egg development results are comparable to the 4-day period reported by Smith (1923) and Cutright (1923), who did not report their temperature conditions. Selhime and Kanavel (1968) obtained egg hatch in 5–6 days at 26.67°C.

The active larval developmental time in our study is one day shorter than that observed by Selhime and Kanavel (1968), who reared their specimens at a similar temperature to ours, but provided their larvae with a mixture of five aphid species, including the cotton aphid. Cutright (1923) obtained an average active larval developmental time of 5.7 days with *B. brassicae* serving as prey. Cutright (1923) and Selhime and Kanavel (1968) reported a mean pupal period of 4.0 and 4.1 days, respectively, which compares favorably with our results.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Cutright (1923) observed that female longevity ranged from 6–36 days (n = 13). Moreover, he recorded a preoviposition period of 3–4 days for 3 females and noted the longest oviposition period was only two weeks. These data are much lower than our observations, but direct comparisons are difficult to make since Cutright did not reveal the temperature regime of his study and used a different prey species.

The mean fecundity of *M. posticus* determined in our study is 6.5-fold higher than the mean of 144 eggs/female reported by Cutright (1923). Our finding of 933 eggs/female is the highest average known for any hemerobiid species. Selhime and Kanavel (1968) obtained a mean egg production of 898 eggs/female for *Micromus subanticus* (Walker). Neuenschwander (1976) observed a mean total egg production of 714.8 eggs/female for *Hemerobius pacificus* Banks; one female produced a maximum of 2554 eggs. Our observed maximum daily clutch size of 58 eggs is equal to that reported by Smith (1923) for *M. posticus*. Cutright (1923), however, reported a maximum of 68 eggs laid by one female in one day.

The attachment of eggs to plant trichomes superficially resembles the stalked eggs of chrysopids and berothids, except in *M. posticus* the point of attachment is on the side. This behavior could represent an intermediate evolutionary step between oviposition in crevices or directly on the substrate and the behavior of forming a stalk for the egg. Other hemerobiid species need to be investigated for this intermediate behavior. Observations of females laying eggs most often on cotton lint in the laboratory also indicate that they have a proclivity to oviposit on something fibrous.

Similar to our observations of *M. posticus* pupation sites in cotton leaf folds, Smith (1923) found cocoons in curled apple leaves. Cutright (1923) suspected *M. posticus* pupated under stones or in the soil, but we found no evidence of this.

The life table data and 1984 field observations indicate that *M. posticus* populations can increase rapidly as long as favorable food and climatic conditions are present. Adults are long-lived and females can produce a large number of eggs which are deposited on a substrate (cotton) that is easily removed. Therefore, this insect may have mass-rearing potential for use in biological control programs against aphids. Inundative or inoculative releases in greenhouses would be particularly inviting because climatic conditions are usually favorable and constant in these structures and the confines of the building prevent dispersion from the target area. The wide range in aphid species fed upon by *M. posticus* gives it an advantage over host-specific parasitoids. In addition, both larval and adult *M. posticus* are predaceous, unlike some chrysopids which are not predaceous in the adult stage. Moreover, Edelson (1982) showed that aphid consumption by *M. posticus* equalled or exceeded that of four other aphidophagous predators. Cutright (1923) reported that first, second, and third instar *M. posticus* larvae consumed an average of 10, 11, and 20 cabbage aphids, respectively. Dunn (1954) found that temperature did not affect the consumption rate of *Micromus variegatus* (F.) a predator of *Acyrthosiphon pisum* (Harris).

Micromus posticus adults and larvae, however, prey on other beneficial species. Cutright (1923) found larvae feeding on coccinellid eggs and eggs of their own species. On a few occasions, we observed adult *M.*

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Figs. 8–10. 8, Egg of *Micromus posticus* attached to cotton trichome. 9, *Micromus posticus* egg attached to spider mite webbing on underside of cotton leaf. 10, *Micromus posticus* cocoons at base of cotton boll within the removed calyx.

posticus biting holes into the mummies of parasitized aphids, and then extracting and devouring the parasitoid larvae. Therefore, *M. posticus* may not be compatible with other aphidophagous biological control agents.

The idea of using lacewings for aphid control in greenhouses was suggested by Reaumur in the 1700's (Flint and van den Bosch, 1981). However, little information has been gathered on the manipulation of hemerobiids as biological control agents. Adequate control of the citrus mealybug, *Planococcus citri* (Risso), was obtained in Palestine by mass releasing *Sympherobius amicus* Navas (Bodenheimer, 1928). Larvae from released *H. pacificus* eggs consistently reduced the aphid population throughout the artichoke growing season in California (Neuenschwander and Hagen, 1980). Hussein (1984) developed a spray technique for the mass release of eggs of *Micromus tasmaniae* Walker in greenhouses and proposed the use of this species in a pest management program for control of pests on potatoes in Australia. Conversely, in the 1930's, eggs of *Hemerobius nitidulus* F. and *H. stigma* were released for control of *Adelges piceae* (Ratzeburg) without apparent success (Garland, 1978).

We hope the information in our study of *M. posticus* will stimulate more investigation into this and other hemerobiid species for use in aphid control.

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